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417-R-GLMPORD-0057
Version 2.0

Geostationary Operational Environmental Satellite (GOES)

GOES-R Series

Geostationary Lightning Mapper (GLM)

Performance and Operational Requirements Document (PORD)

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ATTACHMENT B

May 22, 2007

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

Geostationary Operational Environmental Satellite (GOES)
GOES-R Series
Geostationary Lightning Mapper (GLM)
Performance and Operational Requirements Document (PORD)

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/GLM

GLM PORD

417-R-GLMPORD-0057, RM Version, Geostationary Lightning Mapper (GLM) Performance and Operational Requirements Document (PORD)

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GLMPORD1	1	# 1 Scope
GLMPORD2	1.1	## 1.1 Identification
GLMPORD3	1.1.0-1	This Performance and Operational Requirements Document (PORD) sets forth the performance requirements for the National Oceanic and Atmospheric Administration (NOAA) Geostationary Lightning Mapper (GLM).
GLMPORD4	1.2	## 1.2 Mission Review
GLMPORD5	1.2.0-1	The GLM instrument, designated as GLM in this document, is a single-channel, near-IR optical detector, used to detect, locate and measure the optical pulses associated with lightning over the full-disk at sufficient spatial and temporal resolution to allow tracking of each lightning flash within a specific storm cell and calculation of its optical center over time. The GLM is part of a 3-axis stabilized, geostationary weather satellite system. *(CCR 00348)*
GLMPORD6	1.2.0-2	The GLM objectives are as follows: a) Provide continuous full-disk lightning measurements for storm warning and nowcasting. b) Provide longer warnings of tornado activity. c) Accumulate a long-term database to track decadal changes in lightning activity. The overarching requirement for GLM is a post-processing data product that captures at greater than 70% of the global lightning flashes with a false alarm rate less than 5%. The initial phase of the processing (Level 1b) is to identify optical transient signals (events), which are lightning-induced, from the totality of measurable events. *(CCR 00348) (CCR 01039)*
GLMPORD7	1.2.0-3	The GLM instrument, designated as GLM in this document, provides event data to the GLM Ground System, designated as GLM-GS in this document, via the spacecraft communication system. The GLM-GS takes the GLM data, spacecraft telemetry data, orbit determination data and other required information and autonomously generates calibrated and navigated data for the NOAA users' further data processing. *(CCR 00348)* Data forwarded to the GLM from the spacecraft is not required to be downlinked. This spacecraft data will be available to the GLM-GS as soon as GLM science data is available. *(CCR 00379)* Radiometric calibration is performed before launch. The GLM-GS will be procured separately by the Government but will implement algorithms developed by the GLM contractor to satisfy GLM performance requirements.
GLMPORD8	1.3	## 1.3 Document Overview
GLMPORD9	1.3.0-1	This document contains all performance requirements for the GLM instrument and Ground Support Equipment (GSE). This document, the General Interface Requirements Document (GIRD), and the GLM Unique Instrument Interface Document (UIID) define all instrument-to-spacecraft interfaces for the GLM instrument.
GLMPORD10	1.4	## 1.4 Terminology

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GLMPORD11	1.4.0-1	This document contains all performance requirements for the sensor except those labeled "TBD" and "TBR". The term "TBD," meaning "to be determined," applied to a missing requirement means that the contractor will determine the missing requirement in coordination with the government and the observatory contractor. The term "TBR," meaning "to be reviewed," implies that the requirement is subject to review for appropriateness by the contractor or the government. The government may change "TBR" requirements in the course of the contract.
GLMPORD12	1.5	**1.5 Definitions**
GLMPORD13	1.5.0-1	Throughout this document, the following definitions apply:

Background: A sample value that does not include an event.

Background Image: A scene composed of the background from all detector elements in the focal plane.

CONUS: Defined as a nadir-viewed rectangle 8.0215 x 4.8129 degrees, 5000 East/West x 3000 North/South kilometers, approximately in the geographic area of 10N-50N latitude and 60W-125W longitude.

Detection Probability: Fraction of lightning flashes detected by the GLM. This is computed as an average over the minimum full-disk as defined below with equal weight given to all pixels.

Dynamic Range: Ratio of strongest non-saturated lightning signal to the weakest at 100% albedo with minimum required detection efficiency.

Eclipse: Defined as when the solar disk is completely occulted by the Earth or Moon, as viewed from the GOES satellite.

Event: The occurrence of a sample exceeding the threshold (not to be confused with event-logging or event messages defined in GLMPORD 164 (Section 3.3.5).

Events may include but are not limited to:

a) Optical lightning events
b) Radiation-induced events
c) Surface glint-induced events
d) Electronic noise-induced events
e) Jitter-Induced events

False Alarm Probability: Fraction of GLM flash detections that are not lightning. This is computed as an average over the minimum full-disk as defined below with equal weight given to all pixels.

Fixed-Grid: Refers to the idealized geo-referenced positions for pixel locations. The fixed-grid has the following characteristics:

a) The fixed-grid is rectified to a GRS80 geoid viewed from the idealized geostationary position.
b) The pixels have the same angular separation for East/West and North/South.
c) From the viewpoint of a right-handed coordinate system of the idealized geostationary satellite with its x-axis in the direction of the velocity and the z-axis pointed at nadir, the North/South angle is determined by a rotation about the x-axis and the East/West

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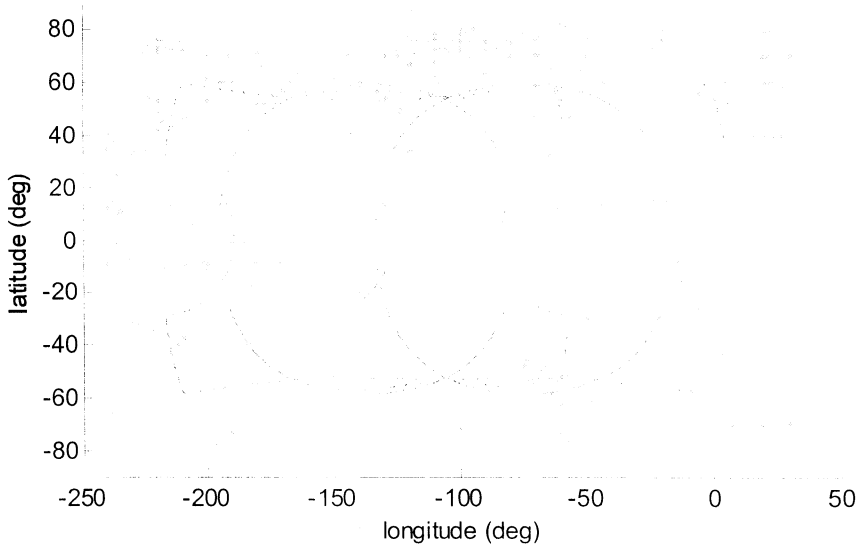
GLMPORD13	1.5.0-1	angle is determined by a rotation about the rotated y-axis.

d) Pixels within an angular radius of 8.66 degrees from the ideal geosynchronous satellite position vector use the ideal satellite as the viewpoint.

Flash: Series of optical lightning pulses grouped by proximity in location and time.

Frame: The set of all samples from a single integration period.

Full Disk: The GLM full-disk is defined as the intersection of circular and square Earth-centered fields-of-view having minimum diameter 16.0° and minimum length 15.1° respectively.



Fully-Functional Configuration: Being able to perform the following functions on-orbit: lightning optical pulse detection, sensor health and status data acquisition, CCSDS packet generation (science, health and status data) plus command reception and execution.

Geolocation: Determination of sample locations on the Earth surface (GRS80 geoid) in terms of latitude and longitude. (This assumes that the GLM sees down to the Earth surface.)

Launch: The period of time between lift off and the separation of the GOES-R series satellite from the launch vehicle.

Level 1b Data: Optical lightning events that have been calibrated, navigated and time tagged.

Navigation: Refers to the determination of sample locations relative to fixed-grid angle coordinates.

Navigation Error: Refers to the angular error of sample locations in the fixed-grid.

Pulse: An optical signal generated by lightning whose nominal duration is on the order of 1 ms. A pulse, as viewed by the GLM, can generate one or more optical events, distributed spatially and or temporally.

Radiant Energy: The integral of object radiance over the instrument integration time.

Sample: Digitized signal from a single physical detector element.

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GLMPORD13	1.5.0-1	Threshold: Minimum amount which a signal must exceed for an event to be detected. Unit: A functional subdivision of a subsystem and generally a self-contained combination of items performing a function necessary for the subsystem's operation. Examples are electronics unit and sensor unit. *(CCR 00219) (CCR 00348) (CCR 00379)*
GLMPORD14	1.5.0-2	All requirements/all performance requirements/all operational requirements: Refers to any performance characteristic or requirement in the GLM PORD, GLM UIID, and the GIRD.
GLMPORD15	1.5.0-3	The requirements in this GLM PORD pertain to the GLM 'system' which may include optics, detectors, signal processing electronics and software, and ground processing. The GLM contractor is not responsible for the whole GLM-GS, but certain GLM specifications, e.g., navigation, will require some level of ground processing after collection but before data distribution. *(CCR 00219)*
GLMPORD16	1.5.0-4	All requirements apply over the entire life of the GLM mission. Data performance requirements, such as navigation, apply to data after level-1b ground processing. *(CCR 00219)*

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GLMPORD17	2	**2 Documents *(CCR 00379)***
GLMPORD268	2.1	**2.1 Applicable Documents *(CCR 00379)***
GLMPORD18	2.1.0-1	The following form a part of this specification to the extent specified herein. GOES-R General Interface Requirements Document, NASA-GSFC, Document Number 417-R-GIRD-0009 GLM Unique Instrument Interface Document (UIID), NASA-GSFC, Document Number 417-R-GLMUIID-0058 CCSDS Recommendation for Space Data System Standards, Lossless Data Compression, CCSDS 121.0-B-1, May 1997. Structural Design and Test Factors of Safety for Spaceflight Hardware, NASA, Document Number NASA-STD-5001, June 21, 1996 General Specification for Assemblies, Moving Mechanical, for Space and Launch Vehicles, Document Number MIL-A-83577B, February 1, 1988 Space Mechanisms Handbook, Document Number NASA TP-1999-206988 General Environmental Verification Standard (GEVS) for GSFC Flight Programs and Projects, Document Number GSFC-STD-7000, April 2005 AFSPCMAN 91-710, Range Safety User Requirements, July 2004 Standard General Requirements for Safe Design and Operation of Pressurized Missile and Space Systems, Document Number MIL-STD-1522, Sept. 4, 1992 *(CCR 00379)*
GLMPORD269	2.2	**2.2 Reference Documents *(CCR 00379)***

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GLMPORD270	2.2.0-1	The following articles provide scientific background based on earlier lightning studies and are provided for reference only. *Algorithm Theoretical Basis Document (ATBD) for the Lightning Imaging Sensor (LIS)*, NASA (H.J. Christian, R.J. Blakeslee, S.J. Goodman, and D.M. Mach), 1 February 2000 "Optical Observations of Lightning from a High-Altitude Airplane", H.J. Christian and S.J. Goodman, *J. of Atmospheric and Oceanic Technology*, vol. 4, December 1987, pp. 701-711 "The Detection of Lightning From Geostationary Orbit", Hugh J. Christian, Richard J. Blakeslee and Steven J. Goodman, *J. of Geophysical Research*, vol. 94, no. D11, September 1989, pp. 13329-13337 "Laboratory Calibration of the Optical Transient Detector and the Lightning Imaging Sensor", William J. Koshak, Mike F. Stewart, Jugh J. Christian, James W. Bergstrom, John M. Hall, and Richard J. Solakiewicz, *J. of Atmospheric and Oceanic Technology*, vol. 17, July 2000, pp. 905-915 "Lightning optical pulse statistics from storm overflights during the Altus Cumulus Electrification Study", D.M. Mach, R.J. Blakeslee, J.C. Bailey, W.M. Farrell, R.A. Goldberg, M.D. Desch, and J.G. Houser, *Atmospheric Research 76 (2005)*, pp. 386-401 *(CCR 00348) (CCR 00379)*

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GLMPORD19	3	**3 GLM Sensor Requirements**
GLMPORD20	3.1	**3.1 GLM Functional Requirements**
GLMPORD21	3.1.1	**3.1.1 GLM Modes**
GLMPORD259	3.1.1.0-1	The contractor may propose additional modes for GLM.
GLMPORD22	3.1.1.1	**3.1.1.1 Safe Mode**
GLMPORD23	3.1.1.1.0-1	The GLM **shall** implement a Safe Mode which is a thermally, electrically and optically safe configuration that protects the instrument from the spacecraft and the environment.
GLMPORD24	3.1.1.1.0-2	The GLM **shall** be maintainable in Safe Mode for an indefinite period of time.
GLMPORD25	3.1.1.1.0-3	The GLM **shall** enter Safe Mode upon receipt of a ground command, receipt of an autonomous safe mode command from the observatory, or detection of internal faults that could cause damage to the instrument. *(CCR 00379)*
GLMPORD26	3.1.1.2	**3.1.1.2 Normal Operational Mode**
GLMPORD27	3.1.1.2.0-1	The GLM **shall** be in a fully functional configuration while in Normal Operational Mode.
GLMPORD28	3.1.1.3	**3.1.1.3 Diagnostic Mode**
GLMPORD29	3.1.1.3.0-1	The GLM **shall** implement a Diagnostic Mode.
GLMPORD30	3.1.1.3.0-2	The GLM **shall** enter Diagnostic Mode only on command. *(CCR 00379)*
GLMPORD271	3.1.1.3.0-3	The GLM **shall,** by command, send dwell data (increased samples per second of a particular telemetry measurand) while in Diagnostic Mode. *(CCR 00379)*
GLMPORD272	3.1.1.3.0-4	The GLM **shall** be in a fully-functional configuration while in Diagnostic Mode. *(CCR 00379)*
GLMPORD273	3.1.1.3.0-5	The GLM **shall,** by command, send all bits from the science data A/D converters while in Diagnostic Mode. *CCR 00379)*
GLMPORD274	3.1.1.3.0-6	The GLM **shall,** by command, suspend downlink of event data and send background images so as to fill the available downlink bandwidth. *(CCR 00379)*
GLMPORD31	3.1.1.3.0-7	The Contractor may add capabilities and functions to the Diagnostic Mode. *(CCR 00379)*
GLMPORD32	3.1.1.4	**3.1.1.4 Survival Mode**
GLMPORD33	3.1.1.4.0-1	The GLM **shall** implement a Survival Mode in which all power is off except for survival heater power, and only passive telemetry is available.
GLMPORD34	3.1.1.5	**3.1.1.5 Mode Transitions**
GLMPORD35	3.1.1.5.0-1	The GLM **shall** transition from any defined mode to any other defined mode upon command.
GLMPORD36	3.1.2	**3.1.2 On-Orbit Operations**
GLMPORD37	3.1.2.1	**3.1.2.1 Zones of Reduced Data Quality**
GLMPORD38	3.1.2.1.0-1	The GLM **shall** meet all operational and performance requirements for all samples whose distance from the center of the un-eclipsed portion of the sun is greater than 10°. *(CCR 00219) (CCR 00348)*

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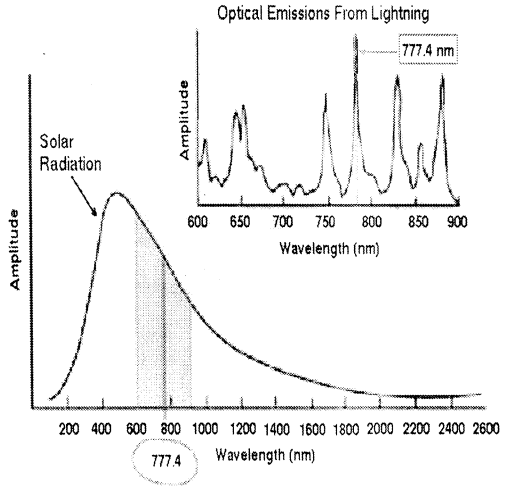
GLMPORD39	3.1.2.1.0-2	For all samples whose distance from the center of the un-eclipsed portion of the sun is between 5° and 10°, the GLM **shall** meet all requirements, except for a two times degradation in the flash detection and false alarm probabilities. *(CCR 00219) (CCR 00348)*
GLMPORD40	3.1.2.2	**3.1.2.2 Solar Intrusion**
GLMPORD42	3.1.2.3	**3.1.2.3 Eclipse**
GLMPORD43	3.1.2.3.0-1	The GLM **shall** operate continuously through eclipse periods.
GLMPORD44	3.1.2.4	**3.1.2.4 Post-Maneuver**
GLMPORD45	3.1.2.4.0-1	The GLM **shall** meet all detection, coverage and navigation requirements after spacecraft attitude has been within specification for 30 minutes following a yaw-flip. *(CCR 00219) (CCR 00348)*
GLMPORD47	3.1.2.4.0-2	The GLM **shall** meet all requirements after spacecraft attitude has been within specification for 30 minutes following a station-keeping maneuver. *(CCR 00348)*
GLMPORD48	3.1.2.4.0-3	The GLM **shall** meet all requirements within 30 minutes of GLM turn-on after being in on orbit storage. *(CCR 00348)*
GLMPORD49	3.2	**3.2 GLM Performance Requirements**
GLMPORD50	3.2.1	**3.2.1 GLM Coverage Requirements**
GLMPORD51	3.2.1.0-1	The GLM **shall** provide continuous optical lightning pulse detection over the full-disk. *(CCR 00219) (CCR 00348)*
GLMPORD54	3.2.2	**3.2.2 GLM Spectral Requirements**
GLMPORD55	3.2.2.0-1	The GLM **shall** measure scene radiant energy centered at 777.4 nm. The lightning spectrum is shown in the Lightning Spectrum Figure below. *(CCR 00219) (CCR 00348)*



Lightning Spectrum Figure

This figure comes from an untitled slide package provided by Hugh Christian.

Discussion: This is the wavelength band used on the TRMM Lightning Imaging Sensor (LIS), and the MSFC LMS study.

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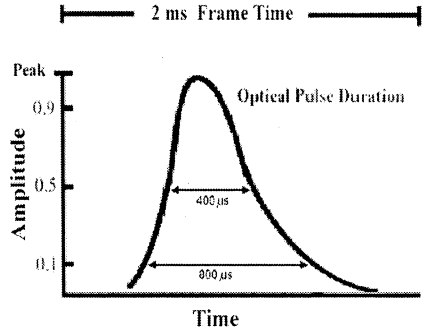
GLMPORD63	3.2.3	**3.2.3 GLM Lightning Detection**
GLMPORD64	3.2.3.1	**3.2.3.1 GLM Basic Detection Requirements**
GLMPORD65	3.2.3.1.0-1	GLM event detection **shall** be autonomous. *(CCR 00219)*
GLMPORD67	3.2.3.1.0-2	The GLM calibration error (radiant energy bias) **shall** be less than 10% of pulse signal strength over the full dynamic range, within the limits of digital resolution, as determined from pre-launch ground calibration. *(CCR 00219) (CCR 00348)*
GLMPORD267	3.2.3.1.0-3	The GLM **shall** report event radiant energy to an accuracy equal to 10% of signal strength over the required dynamic range within the limits imposed by digital resolution. *(CCR 00348)*
GLMPORD69	3.2.3.2	**3.2.3.2 GLM Sensitivity and Dynamic Range**
GLMPORD70	3.2.3.2.0-1	The GLM **shall** detect optical lightning pulses. The average temporal variation of a lightning pulse is shown in the Lightning Pulse Duration Figure below. *(CCR 00219)*



Lightning Pulse Duration Figure

Flashes are composed of multiple pulses. While pulse duration is on the order of a millisecond, flash duration is typically on the order of one second.

GLMPORD74	3.2.3.2.0-2	The flash detection probability **shall** be at least 70% after Level 1b processing. The time span for this computation is 24 hours. *(CCR 00219) (CCR 00348)*
GLMPORD75	3.2.3.2.0-3	The flash false alarm probability **shall** be less than 5% after Level 1b processing. The time span for this computation is 24 hours. *(CCR 00219) (CCR 00348)*
GLMPORD76	3.2.3.2.0-4	The GLM **shall** provide an event dynamic range after background subtraction greater than 100 at all times. *(CCR 00379)*
GLMPORD78	3.2.3.2.0-5	The GLM **shall** be able to detect events in the same detector element in consecutive frames. *(CCR 00219) (CCR 00348)*
GLMPORD275	3.2.3.2.0-6	The GLM **shall** meet its performance requirements throughout the mission despite focal plane degradation. *(CCR 00379)*
GLMPORD79	3.2.3.3	**3.2.3.3 GLM Command and Control Requirements**
GLMPORD80	3.2.3.3.0-1	Receipt and processing of commands and data **shall** not interfere with GLM data collection in any mode. *(CCR 00379)*
GLMPORD81	3.2.3.3.0-2	The GLM **shall** execute commands to individually enable and disable each autonomous function.

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GLMPORD82	3.2.3.3.0-3	The GLM **shall** initiate all commanded mode transitions in no more than 5 seconds after receipt of command. *(CCR 00348)* Note: Exceptions to this requirement are acceptable within the first 60 seconds after a power on, a commanded CPU reset/reboot, or an unplanned CPU watchdog reset. *(CCR 01039)*
GLMPORD83	3.2.3.3.0-4	The GLM **shall** make limits and triggers of autonomous functions changeable by command.
GLMPORD84	3.2.3.3.0-5	The GLM **shall** transition from its current mode to any other mode without causing damage to itself. *(CCR 00379)*
GLMPORD86	3.2.3.3.0-6	The GLM **shall** indicate the instrument mode in housekeeping telemetry.
GLMPORD87	3.2.3.3.0-7	The GLM **shall** provide command and housekeeping telemetry functions in all powered modes. Note: Exceptions to this requirement are acceptable within the first 60 seconds after a power on, a commanded CPU reset/reboot, or an unplanned CPU watchdog reset. *(CCR 01039)*
GLMPORD89	3.2.3.3.0-8	The GLM **shall** provide an event detection threshold that is adjustable by command. *(CCR 00219)*
GLMPORD91	3.2.3.4	**3.2.3.4 GLM Navigation Requirements *(CCR 00219)***
GLMPORD92	3.2.3.4.0-1	The GLM **shall** navigate each optical lightning event. *(CCR 00219)*
GLMPORD93	3.2.3.4.0-2	All navigation requirements listed herein apply to optical lightning events, i.e., the requirements apply to the end-to-end system, taking all instrument, spacecraft and ground processing effects into account. Unless otherwise specified, all navigation requirements in this document are specified in microradians as North/South and East/West angles, 3-sigma, and refer to all hours of operation. In addition, for purposes of this section, 3-sigma is defined as the average ±3 times the square root of the variance for a population of 1000 consecutive observations. *(CCR 00348)* The vendor will be responsible for the navigation algorithm. *(CCR 00219)*
GLMPORD94	3.2.3.4.0-3	The GLM navigation error **shall** not exceed ±112 microradians. *(CCR 00219) (CCR 00348)*
GLMPORD276	3.2.3.4.0-4	The GLM **shall** geolocate each optical lightning event. *(CCR 00379)*
GLMPORD95	3.2.3.5	**3.2.3.5 GLM Data Requirements**
GLMPORD96	3.2.3.5.0-1	The GLM **shall** contribute no more than 10 seconds to the total data latency from event detection through generation of Level 1b products. *(CCR 00348)* Discussion: The GLM contribution to data latency includes delay of data delivery to the spacecraft and delay due to Level 1b ground processing. *(CCR 00219) (CCR 00348)*
GLMPORD97	3.2.3.5.0-2	The GLM **shall** report each event. *(CCR 00219)*
GLMPORD98	3.2.3.5.0-3	The GLM **shall** time tag each event to an accuracy of 1 millisecond. *(CCR 00219)(CCR 00348) (CCR 00379)*
GLMPORD278	3.2.3.5.0-4	The GLM **shall** synchronize its clock with the spacecraft-provided time code and use this time to tag all GLM data. *(CCR 00379)*
GLMPORD99	3.2.3.5.0-5	The GLM **shall** provide the radiant energy of each event. *(CCR 00219) (CCR 00348)*
GLMPORD100	3.2.3.5.0-6	The GLM **shall** provide the threshold used to detect each event. *(CCR 00219)*
GLMPORD101	3.2.3.5.0-7	The GLM **shall** provide the background of each event. *(CCR 00219)*

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GLMPORD102	3.2.3.5.0-8	The GLM **shall** identify the detector element for each event. *(CCR 00219)*
GLMPORD103	3.2.3.5.0-9	The GLM **shall** provide background images autonomously at least once every 5 minutes, or upon ground command. *(CCR 00219) (CCR 00348)*
GLMPORD261	3.2.3.5.0-10	The readout of a background image **shall** not interfere with the detection and reporting of events. *(CCR 00219)*
GLMPORD104	3.2.3.5.0-11	The GLM **shall** provide engineering data, health and safety telemetry, and diagnostic data. *(CCR 00379)*
GLMPORD111	3.3	**3.3 Design Requirements**
GLMPORD112	3.3.1	**3.3.1 Reliability**
GLMPORD113	3.3.1.0-1	The GLM **shall** demonstrate by analysis a Reliability (R) of at least 0.6 after 10 years of on-orbit operations, preceded by up to 5 years of ground storage and up to 5 years of on-orbit storage.
GLMPORD114	3.3.1.0-2	The GLM **shall** demonstrate by analysis a Mean Mission Duration (MMD) of 8.4 years for a design life of 10 years. *(CCR 00348)*
GLMPORD115	3.3.1.0-3	The GLM **shall** provide redundancy to eliminate all credible single-point failures.
GLMPORD116	3.3.1.0-4	The GLM redundant components **shall** be selectable by external command only.
GLMPORD117	3.3.1.0-5	The GLM units of any Flight Model **shall** be interchangeable, without modification, with the equivalent units of any other GLM Flight Model.
GLMPORD118	3.3.1.0-6	The GLM **shall** withstand without damage the sudden removal of operational power.
GLMPORD119	3.3.2	**3.3.2 Mechanical Requirements**
GLMPORD279	3.3.2.1	**3.3.2.1 Design Limit Loads *(CCR 00379)***
GLMPORD120	3.3.2.1.0-1	Each GLM unit structure **shall** possess sufficient strength, rigidity and other characteristics required to survive the critical loading conditions that exist within the envelope of handling and mission requirements.
GLMPORD121	3.3.2.1.0-2	The GLM structures **shall** withstand all limit loads without loss of any required function. *(CCR 00379)* Limit loads are defined as all worst case load conditions including acceleration, vibration and temperature effects from the environments expected during all phases of the structure's service life including manufacturing, ground handling, transportation, environmental testing, integration, pre-launch, launch and on-orbit operations and storage.
GLMPORD280	3.3.2.2	**3.3.2.2 Nonlinear Loads *(CCR 00379)***
GLMPORD122	3.3.2.2.0-1	The GLM structures **shall** withstand redistribution of internal and external loads resulting from nonlinear effects including deflections under load.
GLMPORD281	3.3.2.3	**3.3.2.3 Strength *(CCR 00379)***
GLMPORD123	3.3.2.3.0-1	Structural analysis and design factors of safety **shall** apply to all systems in accordance with NASA-STD-7000 (GEVS) Section 2.2.5. *(CCR 00379)*

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GLMPORD124	3.3.2.3.0-2	While subjected to any operational loads up to yield operational loads, the resulting deformation **shall** not interfere with the operation of the GLM flight units. *(CCR 00379)* Operational load is defined as the expected on-orbit loads while the GLM is operating.
GLMPORD282	3.3.2.4	**3.3.2.4 Reserved *(CCR 00379)***
GLMPORD283	3.3.2.5	**3.3.2.5 Structural Stiffness *(CCR 00379)***
GLMPORD126	3.3.2.5.0-1	Stiffness of the GLM structures and their attachments **shall** be determined by their performance requirements and their handling, transportation and launch environments.
GLMPORD127	3.3.2.5.0-2	Special stowage provisions **shall** be used, if required, to prevent excessive dynamic amplification during handling, transportation and transient flight events.
GLMPORD284	3.3.2.6	**3.3.2.6 Unit Stiffness *(CCR 00379)***
GLMPORD128	3.3.2.6.0-1	The fundamental resonant frequency of the GLM sensor and electronics units **shall** be 50 Hz or greater when the GLM sensor and electronics units are rigidly constrained at their spacecraft interface and the GLM sensor is in its launch configuration. *(CCR 00348)* The fundamental resonant frequency is defined as the lowest mode with more than 2% effective modal mass in any direction. *(CCR 00379)*
GLMPORD129	3.3.2.6.0-2	The GLM sensor and electronics units **shall** survive the spacecraft system level testing with notching of interface forces to design limits only. *(CCR 00379)*
GLMPORD285	3.3.2.7	**3.3.2.7 Material Properties *(CCR 00379)***
GLMPORD130	3.3.2.7.0-1	Material properties **shall** be based on sufficient tests of the material meeting approved specifications to establish design values on a statistical basis.
GLMPORD131	3.3.2.7.0-2	Design values **shall** account for the probability of structural failures and loss of any required function due to material variability.
GLMPORD286	3.3.2.8	**3.3.2.8 Critical Members Design Values *(CCR 00379)***
GLMPORD132	3.3.2.8.0-1	For critical members, design values **shall** be selected to assure strength with a minimum of 99 percent probability and 95 percent confidence. Structural members are classified as critical when their failure would result in loss of structural integrity of the flight units. *(CCR 00379)*
GLMPORD287	3.3.2.9	**3.3.2.9 Redundant Members Design Values *(CCR 00379)***
GLMPORD133	3.3.2.9.0-1	For redundant members, design values **shall** be selected to assure strength with a minimum of 90 percent probability and 95 percent confidence. Structural members are classified as redundant when their failure would result in the redistribution of applied loads to other structural members without loss of structural integrity. *(CCR 00379)*
GLMPORD288	3.3.2.10	**3.3.2.10 Selective Design Values *(CCR 00379)***
GLMPORD289	3.3.2.10.0-1	As an exception to GLMPORD132 [Critical Members Design Values] and GLMPORD133 [Redundant Members Design Values], greater design values may be used if a representative portion of the material used in the structural member is tested before use to determine that the actual strength properties of that particular structural member will equal or exceed those used in the design. *(CCR 00379)*

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GLMPORD290	3.3.2.11	**3.3.2.11 Structural Reliability *(CCR 00379)***
GLMPORD134	3.3.2.11.0-1	The strength, detailed design, and fabrication of the structure **shall** prevent any critical failure, resulting in the loss of any mission objective, due to fatigue, corrosion, manufacturing defects and fracture throughout the life of the GLM.
GLMPORD135	3.3.2.11.0-2	Accounting for the presence of stress concentrations and the growth of undetectable flaws, the GLM structures **shall** withstand loads equivalent to four complete service lifetimes.
GLMPORD136	3.3.2.11.0-3	While subjected to any flight operational load up to limit flight operational loads, the resulting deformation of the residual GLM structures **shall** not interfere with the operation of the GLM units.
GLMPORD137	3.3.2.11.0-4	After any load up to limit loads, the resulting permanent deformation of the residual instrument flight unit structures **shall** not interfere with the operation of the GLM units.
GLMPORD141	3.3.2.12	**3.3.2.12 Mechanisms**
GLMPORD142	3.3.2.12.0-1	Deployment, sensor, pointing, drive or separation mechanisms and other moving mechanical assemblies may be designed using MIL-A-83577B and NASA TP-1999-206988.
GLMPORD143	3.3.2.12.0-2	GLM mechanisms **shall** meet performance requirements while operating in an Earth gravity environment with any orientation of the gravity vector. *(CCR 00348)*
GLMPORD144	3.3.2.12.0-3	GLM moving mechanical assemblies **shall** provide torque and force ratios per section 2.4.5.3 of GSFC-STD-7000 using the following factors of safety.

Program Phase	Known Torque Factor of Safety (FS_k)	Variable Torque Factor of Safety (FS_y)
Preliminary Design Review	2.0	4.0
Critical Design Review	1.5	3.0
Acceptance/Qualification Test	1.5	3.0

(CCR 00379)

GLMPORD145	3.3.2.12.0-4	Rotational GLM actuators **shall** provide a continuous maximum torque output greater than 7.0 milli-Nm for all operating points of the actuators.
GLMPORD146	3.3.2.12.0-5	Linear GLM actuators **shall** provide a continuous maximum force output greater than 0.28 N for all operating points of the actuators.
GLMPORD147	3.3.2.12.0-6	GLM mechanisms using closed-loop control **shall** provide gain and phase margins greater than 12 dB and 40°, respectively, including the effects of the dynamic properties of any flexible structure.
GLMPORD148	3.3.2.12.0-7	GLM mechanisms requiring restraint during launch **shall** be caged during launch without requiring power to maintain the caged condition.
GLMPORD149	3.3.2.12.0-8	GLM mechanisms requiring restraint during launch **shall** be released from the caged condition by command.
GLMPORD150	3.3.2.12.0-9	GLM mechanisms requiring restraint during launch **shall** be returned to a caged condition ready for launch by either command or by manual actuation of an accessible caging device.
GLMPORD291	3.3.2.13	**3.3.2.13 Pressurized Units *(CCR 00379)***
GLMPORD292	3.3.2.13.0-1	GLM pressurized systems **shall** follow the requirements in accordance with AFSPCMAN 91-710 and MIL-STD-1522A for the design of pressurized systems. *(CCR 00379)*

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GLMPORD293	3.3.2.13.0-2	The GLM **shall** have no open fluid reservoirs when delivered to the spacecraft contractor. *(CCR 00379)*
GLMPORD294	3.3.2.14	**3.3.2.14 Alignment Reference *(CCR 00379)***
GLMPORD295	3.3.2.14.0-1	The GLM sensor unit **shall** provide a permanent flight worthy optical alignment reference composed of a minimum 2.54 cm alignment cube and a mounting surface datum. *(CCR 00379)*
GLMPORD296	3.3.2.14.0-2	The GLM **shall** provide a flight worthy cover for the optical alignment cube. Flight worthy cover means that the cover will capture the cube should it separate from the spacecraft during launch. *(CCR 00379)*
GLMPORD297	3.3.2.14.0-3	The GLM sensor unit **shall** provide fiduciary marks locating the X, Y, and Z axes of the unit. *(CCR 00379)*
GLMPORD298	3.3.2.15	**3.3.2.15 Precision Component Assembly *(CCR 00379)***
GLMPORD299	3.3.2.15.0-1	When precise location of a component is required, the design **shall** use a stable, positive location system without relying on friction as the primary means of attachment. *(CCR 00379)*
GLMPORD151	3.3.3	**3.3.3 Thermal Requirements**
GLMPORD152	3.3.3.0-1	The GLM contractor **shall** establish Mission Allowable Temperatures (MAT) for the GLM accommodating at least 5 K of analytical/test uncertainty at each temperature extreme. Thermal margin is defined as the temperature delta between MAT versus the bounding predictions plus analytical uncertainty.
GLMPORD153	3.3.3.0-2	The GLM **shall** maintain thermally independent units and their internal components within MAT limits during all flight operational conditions including bounding worst-case environments.
GLMPORD154	3.3.3.0-3	The GLM **shall** survive without damage over the Non-Operational Temperatures (NOT) range extending from at least 20 K warmer than the hot MAT and at least 20 K colder than the cold MAT. *(CCR 00379)*
GLMPORD155	3.3.3.0-4	The GLM cold NOT **shall** be 248 K or colder. *(CCR 00379)*
GLMPORD156	3.3.3.0-5	The GLM **shall** provide two or more serial and independent controls for disabling any heater where any failed on condition would cause over-temperature conditions or exceed the instrument power budget.
GLMPORD157	3.3.3.0-6	The GLM heaters **shall** be sized to provide 25% margin for worst case conditions.
GLMPORD158	3.3.3.0-7	The GLM survival heaters **shall** be thermostatically controlled.
GLMPORD159	3.3.4	**3.3.4 Onboard Processors Requirements**
GLMPORD160	3.3.4.0-1	The entire GLM flight software image **shall** be contained in non-volatile memory at launch.
GLMPORD161	3.3.4.0-2	The GLM **shall** provide for reset of the On-board Processor by command.
GLMPORD162	3.3.4.0-3	The GLM On-Board Processor **shall** initialize upon power-up into a predetermined configuration.
GLMPORD163	3.3.4.0-4	The GLM **shall** provide a fail-safe recovery mode dependent on a minimal hardware configuration capable of accepting and processing a minimal command subset sufficient to load and dump memory.

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GLMPORD164	3.3.5	**3.3.5 Flight Software Requirements**
GLMPORD165	3.3.5.0-1	All software developed for the GLM instrument **shall** be developed with ANSI/ISO standard languages and a widely-accepted, industry-standard, formal software design methodology. With NASA approval, minimal use of processor-specific assembly language is permitted for certain low-level programs such as interrupt service routines and device drivers.
GLMPORD166	3.3.5.0-2	The GLM flight software **shall** be re-programmable on-orbit without computer restart.
GLMPORD167	3.3.5.0-3	The GLM flight software **shall** be uploadable in Computer Software Units (CSUs) and usable immediately after completion of the modified unit upload.
GLMPORD168	3.3.5.0-4	Activation of the modified GLM CSUs **shall** not require completion of an upload of the entire flight software image.
GLMPORD169	3.3.5.0-5	The GLM flight software **shall** be deterministic in terms of scheduling and prioritization of critical processing tasks to ensure their timely completion.
GLMPORD170	3.3.5.0-6	All GLM software data that are modifiable and examinable by ground operators **shall** be organized into tables that can be referenced by table number so table data can be loaded and dumped by the ground without reference to memory address.
GLMPORD171	3.3.5.0-7	The definition of GLM commands within the ground database **shall** not be dependent on physical memory addresses within the flight software.
GLMPORD172	3.3.5.0-8	All GLM software and firmware versions **shall** be implemented with an internal identifier (embedded in the executive program) that can be included in the instrument engineering data.
GLMPORD173	3.3.5.0-9	The GLM software internal identifier **shall** be keyed to the configuration management process.
GLMPORD174	3.3.5.0-10	During development, GLM flight processors providing computing resources for instrument subsystems **shall** be sized for worst case utilization not to exceed the capacity shown below (measured as a percentage of total available resource capacity): **Flight Processor Resource Utilization Limits**

	S/W PDR	S/W CDR	S/W AR
RAM Memory	40%	50%	60%
ROM Memory	50%	60%	70%
CPU	40%	50%	60%

GLMPORD196	3.3.5.0-11	The GLM flight software **shall** provide time-tagged event logging in telemetry.
GLMPORD197	3.3.5.0-12	The GLM event messages **shall** include all anomalous events, mode transitions, and system performance events.
GLMPORD198	3.3.5.0-13	All GLM flight software components **shall** utilize a common format for event messages.
GLMPORD199	3.3.5.0-14	GLM flight software **shall** provide commands to enable and disable queuing of individual event messages.
GLMPORD200	3.3.5.0-15	GLM flight software **shall** buffer a minimum of 1000 event messages while the event messages are queued for telemetering to the ground. *(CCR 00348)*

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GLMPORD201	3.3.5.0-16	The GLM event message queue **shall** be configurable by command to either a) discard the new event messages, or b) overwrite oldest event messages when the queue is full. *(CCR 00379)*
GLMPORD301	3.3.5.0-17	The GLM **shall** downlink new event messages whether the event message queue is overwriting or discarding new event messages. *(CCR 00379)*
GLMPORD302	3.3.5.0-18	The GLM **shall** downlink event messages to the event message queue whenever GLM receives operational power from the spacecraft. *(CCR 00379)*
GLMPORD202	3.3.5.0-19	GLM flight software **shall** maintain counters for: a) the total number of event messages generated b) the number of event messages discarded because of queue overflow c) the number of event messages not queued due to being disabled
GLMPORD203	3.3.5.0-20	GLM flight software **shall** provide a restart by command with preservation of the event message queue and memory tables.
GLMPORD204	3.3.5.0-21	GLM flight software **shall** provide a mechanism to verify the contents of all memory areas.
GLMPORD205	3.3.5.0-22	GLM flight software, and associated on-board computer hardware, **shall** provide for dumping any location and any size of on-board memory to the ground upon command.
GLMPORD206	3.3.5.0-23	The GLM flight software memory dump capability **shall** not disturb normal operations and instrument data processing.
GLMPORD207	3.3.5.0-24	Telemetry points sampled by the GLM **shall** be controlled by an on-orbit modifiable table.
GLMPORD208	3.3.5.0-25	The sample rate of every GLM telemetry point **shall** be controlled by an on-orbit modifiable table.
GLMPORD209	3.3.6	**3.3.6 Power Requirements**
GLMPORD210	3.3.6.0-1	The GLM power regulators and supplies **shall** provide a phase margin of greater than 35 degrees.
GLMPORD211	3.3.6.0-2	The GLM power regulators and supplies **shall** provide a gain margin of greater than 20 dB.
GLMPORD212	3.3.6.0-3	The GLM **shall** not contain fuses.
GLMPORD213	3.3.6.0-4	The GLM **shall** provide flight qualified covers for all test point connectors.
GLMPORD214	3.3.7	**3.3.7 Magnetic Properties**
GLMPORD215	3.3.7.0-1	The change in the magnetic field produced by the GLM sensor, electronics, or power supply modules **shall** be less than 30 nanotesla peak-to-peak for any operating mode, up to a low-pass bandwidth of 4.0 Hz, along any axis when measured at a distance of 1 meter from any face of a module.
GLMPORD216	3.3.8	**3.3.8 Spacecraft Level Ground Testing**
GLMPORD217	3.3.8.0-1	The GLM **shall** accommodate operational testing in all modes and states for indefinite periods during Spacecraft level Thermal Vacuum Testing in at least the following two orientations: 1) Spacecraft +Y axis aligned with the gravity vector and pointed down. 2) Spacecraft -X aligned with the gravity vector and pointed down. *(CCR 00348)*

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GLMPORD218	3.3.9	**3.3.9 Electrical System Test Equipment**
GLMPORD219	3.3.9.0-1	The Electrical System Test Equipment (ESTE) **shall** operate the GLM and electrical ground support equipment during performance verification and calibration testing.
GLMPORD220	3.3.9.0-2	The ESTE **shall** simulate the spacecraft interface with power, clock pulses, command, and telemetry functions.
GLMPORD221	3.3.9.0-3	The ESTE **shall** include all test equipment necessary to operate and control the GLM in all phases of operation and test modes.
GLMPORD222	3.3.9.0-4	The ESTE **shall** generate and maintain command logs.
GLMPORD223	3.3.9.0-5	The ESTE **shall** limit check all health and safety data.
GLMPORD224	3.3.9.0-6	The ESTE **shall** capture and archive all raw GLM data.
GLMPORD225	3.3.9.0-7	The ESTE **shall** provide near real-time and off-line data analysis of all GLM data necessary to determine the performance characteristics of the instrument. *(CCR 00379)*
GLMPORD226	3.3.9.0-8	The ESTE **shall** interface with the Spacecraft Ground Support Equipment at the Spacecraft Contractor's facility to extract GLM science and engineering data.
GLMPORD227	3.3.9.0-9	The ESTE **shall** prohibit hazardous or critical commands being sent to the GLM without operator verification.
GLMPORD228	3.3.10	**3.3.10 Flight Software Development Environment**
GLMPORD229	3.3.10.0-1	The Flight Software Development Environment (FSDE) **shall** consist of the hardware and software systems used for real-time, closed-loop testing on flight-like hardware to develop, test, verify, and demonstrate that the flight software is ready for Government acceptance. *(CCR 00379) (CCR 01035)*
GLMPORD230	3.3.10.0-2	The FSDE **shall** support all lifecycle activities (development, test, and validation) simultaneously.
GLMPORD231	3.3.10.0-3	The FSDE **shall** contain all items (software, databases, compilers, debuggers, etc.) needed to prepare flight software for the target processor.
GLMPORD232	3.3.10.0-4	The FSDE **shall** contain engineering (hardware) models of necessary flight hardware as well as dynamic software models comprising the remainder of the instrument and the necessary on-orbit environment.
GLMPORD233	3.3.11	**3.3.11 Shipping Containers**
GLMPORD234	3.3.11.0-1	The GLM shipping container **shall** be compatible with shipment by air or air-ride van.
GLMPORD235	3.3.11.0-2	The GLM shipping container **shall** be purgeable, and electrically equipped for testing instrument aliveness while in storage, without opening.
GLMPORD236	3.3.11.0-3	The GLM shipping container **shall** have internal temperature, humidity, and pressure monitors with external indicators.
GLMPORD237	3.3.11.0-4	The GLM shipping container **shall** have shock recorders.
GLMPORD238	3.3.11.0-5	The GLM shipping container **shall** meet all contamination control requirements imposed on the GLM instrument units.
GLMPORD239	3.3.11.0-6	The GLM GSE shipping container(s) **shall** be compatible with shipment by air or air ride van.

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GLMPORD242	3.3.12	**3.3.12 GLM Emulator**
GLMPORD243	3.3.12.0-1	The GLM emulator **shall** simulate all instrument modes and mode transitions.
GLMPORD244	3.3.12.0-2	The GLM emulator **shall** simulate predefined, scripted anomalies.
GLMPORD245	3.3.12.0-3	The GLM emulator **shall** communicate with a spacecraft emulator for instrument command, telemetry, and science packets using Space Wire.
GLMPORD246	3.3.12.0-4	The GLM emulator **shall** use commercial power.
GLMPORD247	3.3.12.0-5	The GLM emulator **shall** execute GLM flight code.
GLMPORD248	3.3.12.0-6	The GLM emulator **shall** accept simulation control commands from a standalone console.
GLMPORD249	3.3.12.0-7	The GLM emulator **shall** accept simulation control commands from the spacecraft emulator.
GLMPORD250	3.3.12.0-8	The GLM emulator **shall** generate housekeeping data reflective of commanded mode.
GLMPORD251	3.3.12.0-9	The GLM emulator **shall** accept real-time inputs to change simulated telemetry or modeling parameters.
GLMPORD252	3.3.12.0-10	The GLM emulator **shall** maintain a log of all instrument commands received indicating validity, command mnemonic, and raw bit pattern.
GLMPORD253	3.3.12.0-11	The GLM emulator **shall** maintain a log of all simulation directives received.

GLMPORD254 4

4 Acronyms

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GLMPORD255 4.0-1

A/D	analog-to-digital
ABI	Advanced Baseline Imager
ANSI	American National Standards Insititute
AR	acceptance review
CDR	critical design review
cm	centimeter
CONUS	continental United States (excluding Alaska and Hawaii)
CPU	central processing unit
CSU	computer software units
CTE	coefficient of thermal expansion
EOL	end-of-life
ESD	electrostatic discharge
ESTE	electrical system test equipment
FOV	field-of-view
FSDE	flight software development environment
GEVS	General Environmental Verification Specification
GIRD	General Interface Requirements Document
GLM	Geostationary Lightning Mapper
GOES	Geostationary Operational Environmental Satellite
GS	ground system
GSD	ground sample distance
GSE	ground support equipment
INR	image navigation and registration
ISO	International Organization for Standardization
J	joules
K	Kelvin
km	kilometers
LIS	Lightning Imaging Sensor
LMS	Lightning Mapping Sensor
m	meters
MAT	mission allowable temperature
MMD	mean mission duration
MRD	Mission Requirements Document
ms	milliseconds
N	Newtons
NASA	National Aeronautics and Space Administration
NBOF	narrow-band optical filter
NEDN	noise equivalent delta radiant energy
nm	nanometer
Nm	Newton-meter
NOAA	National Oceanic and Atmospheric Administration
NOT	non-operating temperature
OTD	Optical Transient Detector
PDR	Preliminary Design Review
PORD	Performance Operational Requirements Document
RAM	random access memory
ROM	read-only memory
SNR	signal-to-noise ratio
sr	steradian
S/W	software
TBD	to be determined
TBR	to be reviewed
TBS	to be supplied
TRMM	Tropical Rainfall Mapping Mission
UIID	Unique Instrument Interface Document

(CCR 00348)

417-R-GLMPORD-0057 DCR

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DOORS Version: GLMPORD 1.1 Inc in: 1.2
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Title: GLM RFP PORD Changes
GOES S/C: R Effectivity: GLM Instrument
Doc #: 417-R-GLMPORD-0057
Doc Section All
DOORS Version: 1.2 Inc in: 1.3
DOORS ID #: All

CCR #: 01035 Rev
Contract # NNG0 – (RFP)
CCB Status: **Approved**
CCB Date: 5/07/2007
Contract Mod#:
Doc Change Date: 5/22/2007

Title: GLM RFP PORD Changes
GOES S/C: R Effectivity: GLM Instrument
Doc #: 417-R-GLMPORD-0057
Doc Section All
DOORS Version: 1.3 (Inc in 2.0)
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CCR #: 01039 Rev
Contract # NNG0 – (RFP)
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